RESEARCH ARTICLE

Optimal Location and Sizing of Series FACTS device to Minimization of Power Loss and Voltage Magnitude

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ABSTRACT: Every day, power piques our curiosity more and more. As a result, there is a quick power exchange that creates challenging power transmission issues as well as a stampeded increase in booked power that flows through the transmission line. Building more transmission lines or boosting the load capacity of the ones that already exist can remedy this issue. The cost-effectiveness of constructing new lines enables the proper positioning of (FACTS) devices to address this problem. This study suggests the artificial bee colony (ABC) algorithm and genetic algorithm as a method for selecting the ideal site and size. In this attempt, three objectives were taken into consideration. They are reducing installation costs and increasing system capacity to handle load and transmission loss. Transmission loss and costs Putting and sizing the FACTS devices in the ideal locations to minimize real power loss (PL), improve the voltage profile (VD), and boost voltage stability are just a few examples of modern nonlinear mathematical problems that can be solved using the objective of ABC and GA method. The findings demonstrate that power flows are greatly improved, and a higher voltage is generated. In electrical networks, voltage control and power loss reduction should be carried out as effectively as feasible. A novel method is presented to locate FACTS devices in a multi-machine power system optimally using ABC and Genetic Algorithm (GA). The recommended course of action using the optimization techniques and accounting for the temperature and voltage restrictions as well as to accurately assessing the number of devices and their ratings were discussed. The proposed technique is examined for use on the IEEE 5 and IEEE 14-bus systems, and it is determined that ABC is superior to GA optimization for loss reduction.

KEYWORDS: FACT, GA, ABC, PL, Genetic Algorithm

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1. INTRODUCTION

In the latter half of 1980, the Electric Power Research Institute (EPRI) of the USA unveiled the Flexible AC Transmission Systems (FACTS). To enhance controllability and increase power transfer capacity, a power electronic-based system known as FACTS is said to have additional static equipment and control one or more AC transmission system parameters [1-3]. It is capable of swiftly and effectively controlling the line impedance, voltage magnitude at a few buses, and phase angle of the transmission system. It also controls the flow of both active and reactive power over a line [4-5]. The ideal location of Flexible AC Transmission Systems equipment in a mesh network provides power flow management, enhancing the system's ability to support loads. It has been demonstrated that a fixed number of devices cannot be increased past this load in general, carrying capacity For the steady-state analysis, three different types of devices have been used and each has been modeled. These gadgets are used to increase the quantity of power transmitted by the network by managing the power flows. In combinatorial analysis, locating the best locations for the specified number of FACTS devices becomes difficult. ABC and Genetic Algorithms have been chosen to solve this type of problem. Most studies on how to install FACTS devices are either technical, economic, or cover both [6-7]. There are some technical issues with the suggested method's practical installation of numerous FACTS devices at diverse sites to detect the rise in load capabilities. The genetic algorithm has been utilized to choose the approach security with increased load capacity. Choose the best locations for installing FACTS. In the design and operation of power systems, voltage instability has been a serious problem [9–10]. Voltage instability happens when voltage stability does not, which results in a gradual voltage decline.

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Voltage instability has been connected to several important network failures recently. Modern power transmission networks like FACTS devices assist in making power systems more reliable and effective [11–12]. To make better use of transmission lines, use FACTS devices to control the flow of reactive power [13]. FACTS devices can also significantly reduce voltage sags. A novel method is presented to locate FACTS devices in a multi-machine power system optimally using ABC and Genetic Algorithm (GA). The recommended course of action, using the optimization technique, and taking into To determine the number of devices and their ratings in the most accurate manner possible while taking heat and voltage limits into consideration.

2. *Problem Statement*

The enhancement of voltage stability is one of the hardest power system problems. Along with ABC optimization being used to reduce reactive and actual power loss, a genetic algorithm-based solution for enhancing voltage stability and reducing loss is also offered. The Newton-Raphson method is used to perform the load flow analysis using the MATLAB software package. The reactive compensation parameters are modeled into the power flow equation to determine the reactive power injection quantity. To lower the overall power loss in the power system network, the required amount of reactive power is determined using a genetic algorithm and ABC. The system's overall power loss is recorded, compared to the scenario, and the average case. is the usual situation, the case where the load power increases abruptly, and the situation where variable reactive power is added. Total power lost across the board increases for the system without reactive power injection whereas it decreases for the system with reactive power injection in the ideal configuration. The findings generated using the suggested method are judged to deliver the least amount of real power loss when compared to the load flow strategy based on Newton-Raphson, enhancing the voltage stability of the power system.

3. *Proposed Approach*

The main objective, in this case, is to lower transmission loss by adding FACTS devices in key locations across the transmission network. The addition of a FACTS controller increases system costs as well. Therefore, it is essential to place FACTS devices in the best positions feasible so that, even when expensive FACTS devices are used, the benefit of reduced transmission loss must still be discernible. The cost functions of the various FACTS devices are considered and linked by the objective function in this situation. The best results were obtained using a device that was placed optimally based on weak bus identification and a case study of the IEEE 5 bus and IEEE 14 bus. However, FACTS can be used to observe both the active and reactive power flow patterns. The active and reactive power flow patterns can be changed and significant system performance is noticed.

4. *Optimization Technique*

Two optimization methods have been identified for the examination of the ideal placement of a data collection device. Genetic algorithms (GAs) are methods for doing international searches. They are not necessary to be familiar with any prerequisite information or particulars of the intended function. They can also look for several different options at once. Additionally, they consistently deliver top-notch services, making them useful resources for locating the ideal solution to a challenging issue. GA uses probabilistic transition rules in place of deterministic rules. The Artificial Bee Colony approach is then used to analyze the best position to put the facts device on the IEEE bus system. It is a technique for the honeybee swarm's complex foraging behavior. The first step is the initial scout bee population, which is established by the quantity and these devices may be found in various numbers, types, and locations [13–16]. The fitness computation method is then carried out by calculating the ATC for each site that a bee visits. Next, the neighborhoods that the chosen bees visited for neighborhood search are picked, and the bees with the best fitness are chosen as the chosen bees. Moreover, the breadth of the bee's local searches at the selected places. Based on the projected size, the computer then conducts searches close to the selected places. Because more bees are tasked with seeking close to the finest regions, the ideal sites can be selected based on the benefits associated with them. The remaining bees are then sent out in a random search to find new potential locations. The top worldwide locations were then determined, and a new population was generated at random. Another technique that has been applied is the frequency response methodology, which has been explored. Where he proposed that the damping power oscillations effect might be reduced by using frequency response to install locations and input control signals of FACTS-based stabilizers. Effects of transmission line oscillations. This method also requires for an examination of the alternative sites to select the best location, the best input control signal, and the best feedback signal. In this strategy, the location of the FACTS devices has been continuously and randomly changing.

5. *Facts Controllers Locations*

It is ideal to require FACTS devices to be properly connected to the electrical system since FACTS controllers that are incorrectly positioned fail to provide optimal performance and can even be counterproductive. Because of this, the location of these devices is crucial [17]. According to some literature, attaching a series of FACTS device to the line's middle offers the line's greatest benefits. This was the case based on a skewed line model that ignored the resistance and line capacitance. The results, however, are very different. In more recent papers, such as [18-19], where real-world events are carefully considered, the precise model of the line is carefully compared to those predicted for the simpler model. It is demonstrated in this piece of work that placing the device slightly off-center from the transmission line's center, as opposed to in the center, offers the most advantages. Additionally, it has been demonstrated that optimal distances from the center point rely on line resistance and grow linearly with the line R/X ratio. Contrary to what many academics asserted in the case of uncompensated lines, it has been shown that the positioning of the FACTS device alters as the level of series compensation changes, the device changes. Additionally, the series' degree is nearly linear. The location of the increment in the degree of series compensation shifts from the center point to the generator side when the degree of series compensation is increased.

6 . *Location Criteria for the Facts Device*

Stability indices, control theories, artificial intelligence techniques, sensitivity, frequency response, nodal analysis, and point of voltage collapse technique-based approaches are just a few of the variables that affect where these devices should be placed. Generally, the location of FACTS equipment depends on the installation's objectives. FACTS by increasing system load Power networks may contain equipment for a range of uses, and their locations can be discovered using several different techniques. FACTS devices, for instance, can be used to control power flow, enhance dynamic stability, and make up for reactive power and voltage instability. The bee's algorithm is a genetic algorithm (GA) (BA). Installing various FACTS device types and figuring out where they should be placed in the system are much more difficult tasks. The improvement of one method for figuring out where and how many FACTS devices to utilize is to optimize the ABC and GA methodology. Before the initial population of individuals is produced in the normalized form to comply with the FACTS device's constraints, the ABC and GA technique first accepts bus data, line data, and the number of FACTS devices as inputs.

7. *Optimization Algorithm of GA AND ABC*

The procedure of the algorithm considered in this work is given below.

Step 1. ABC parameters and mathematically modeled systems constraints such as real power generation, voltage magnitude, and the location of shunt FACTS devices are defined.
Step 2. A randomly generated initial vector is achieved by using (1).
Pij=Pjmin+ran*(Pjmax-Pjmin)

Step 3. Evaluate the objective function values and so the fitness values by using equation (2).

$$\text{Fitnessi}=\begin{bmatrix} 1/(1+\text{fi}),0\leq fi \\ 1+\text{abs(fi)},0>\text{fi} \end{bmatrix}$$

Step 4. A new solution set vector is generated corresponding to (3). The objective function and fitness for newly generated solution sets are evaluated by using optimal power flow. Pijnew=Pij+$\emptyset$ ×(Pij-Pkj) (3)

Step 5. The probability function, which is unique for the ABC algorithm, is achieved and evaluated by using (4) which leads to evaluating the fitness value and selecting the best solution set for each food source. SN defines the number of the population chosen by the user. Pi=fitness/$\sum_{i=1}^{SN} fitness$ I (4)

Step 6. If the current solution set cannot be improved after trying up to the limit defined by a user, that solution set is abandoned and a new one is created by jumping to Step 2.

Step 7. The best solution set achieved this far is memorized. The function loop is stopped if the criterion is met; otherwise the algorithm jumps to Step 4 and continues the iteration process. A flowchart of the artificial bee colony algorithm is given in Figure 5.

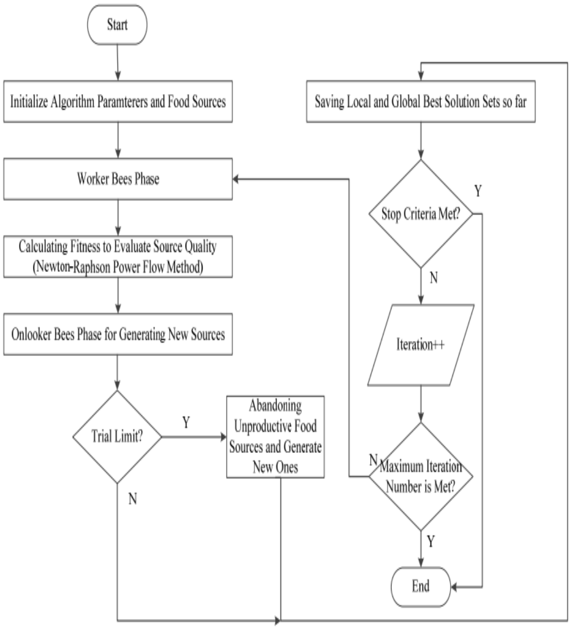
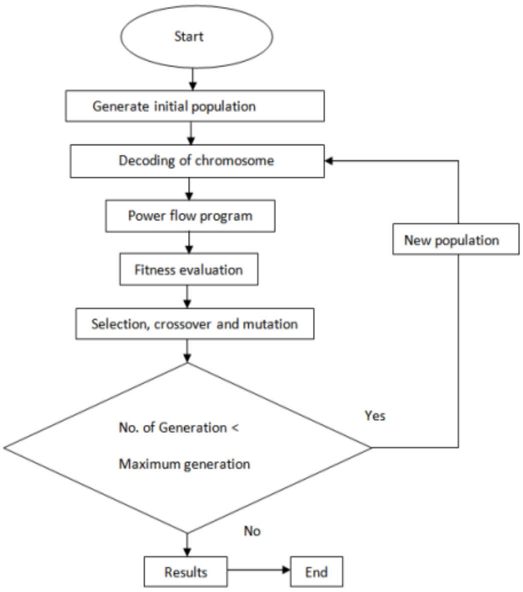

Start
Initialize Algorithm Paramterers and Food Sources
Worker Bees Phase
Calculating Fitness to Evaluate Source Quality (Newton-Raphson Power Flow Method)
Onlooker Bees Phase for Generating New Sources
Trial Limit?
Y
N
Abandoning Unproductive Food Sources and Generate New Ones
Saving Local and Global Best Solution Sets so far
Stop Criteria Met?
Y
N
Iteration++
N
Maximum Iteration Number is Met?
Y
End

Figure 1 flow chart of ABC optimization

7. b Genetic algorithm

A brief description of the components is as below:
The following is the suggested algorithm for utilizing GA to deploy SVC devices in the best possible positions:

Step 1: Establish a baseline population
Step 2: Run the Power Flow software
Step 3: Determine each person's fitness level.
Step 4: Choose a new population from the old population based on the evaluation function's assessment of each person's fitness.
Step 5: Use genetic operators (mutation and crossover) on population members to generate fresh ideas.
Step 6: is to assess the fitness of new chromosomes and introduce them to the population.
Step 7: If the number of iterations has been reached, halt and bring back the top candidate; otherwise, move on to step 4.



8. RESULTS AND DISCUSSION

The proposed methodology is examined using the IEEE 5 and IEEE 14 bus test system. The appropriate sections contain the parameters for various test systems, and the parameter sets for ABC are based on a trial-and-error process. In each case, the effectiveness of the series facts device is discussed concerning enhancing power flow using MATLAB coding, the size and location of the facts device are dependent on the reactive power flow in the line. Using ABC algorithm method, which is also utilized to find the optimal location, is contrasted with the suggested non-traditional approach. The suggested methodology removes the complication of minimizing loss and improving the voltage profile using both methods and discussing which method provides good result after analyzing the case study of the IEEE benchmark which is shown in the figure

Case 1: 5 bus system

The efficiency of the series facts device to increase the power flow is shown in Table 1 and it will be installed in various locations in the five-bus test system. By adding two fake lines, the five-bus test system is upgraded to include a series facts device. The total load on the system is 165 MW. MCN is assumed to be 100, and the colony size for ABC is set at 20. , the parameters for Series FACTS device GA and ABC are established. The findings for two lines are shown in the table, together with the ideal location for active power dispatch, bus voltages, losses, and real power flow, and real power generation size of the Facts device Using actual and reactive power injection of the appropriate magnitude, the ABC optimization technique, which improves the power flow in the line, improves the power flow through the lines. It is evident from Table 1 that the line is the ideal location.

Case 2: IEEE 14 bus system

In this numerical illustration, a series facts device is integrated into an IEEE 14 bus system, and the ideal location is chosen using the suggested GA method and the ABC algorithm. Table 1 lists the FACTS Device's capacity to enhance active power import. The IEEE 14 bus system's series facts device is installed in every conceivable location, and Table 1 of both method provides the various outcomes (Optimal power distribution, actual power flow, actual power loss, the actual cost of power production, installation costs series facts device which is given by different plot

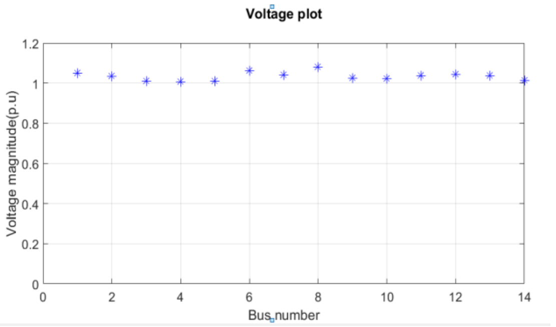


Figure 3: voltage magnitude concerning bus no without Optimization

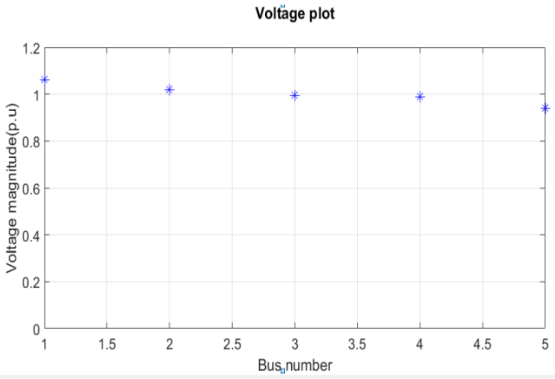


Figure 4: voltage magnitude concerning bus no without Optimization

The inference drawn from the Table 1 is for the IEEE 14 bus system the ABC is the best method for the reduction of loss and increase in voltage magnitude as compared to the GA optimization method but in the case of the IEEE 5 bus also as for loss is concern the real power loss are very less in ABC method as compared to GA optimization method hence concluded that from table ABC is the best method to place the facts device to reduce the loss in the system and improve the voltage profile without facts device and optimization technique loss will be higher and power flow will be reduced and voltage magnitude will be maintained constant throughout the system performance.

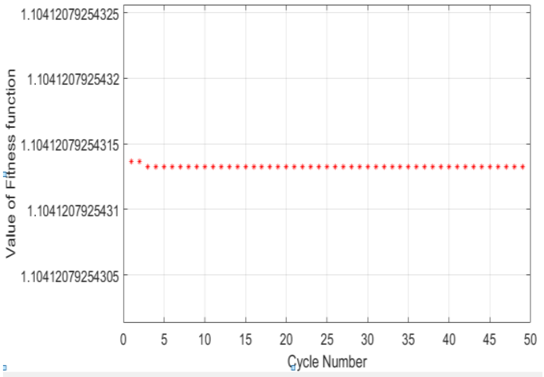


Figure 5: fitness plot with cycle no for IEEE 14 bus with ABC optimization

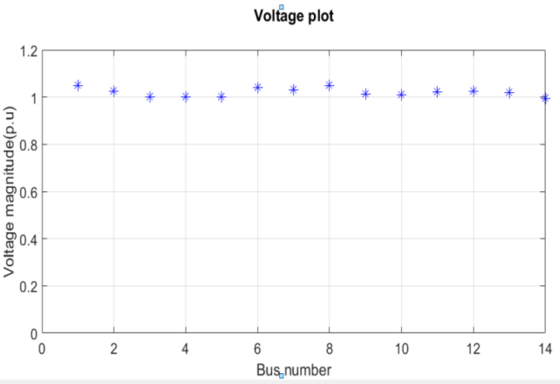


Figure 6: Voltage magnitude with bus no for IEEE 14 bus with ABC optimization

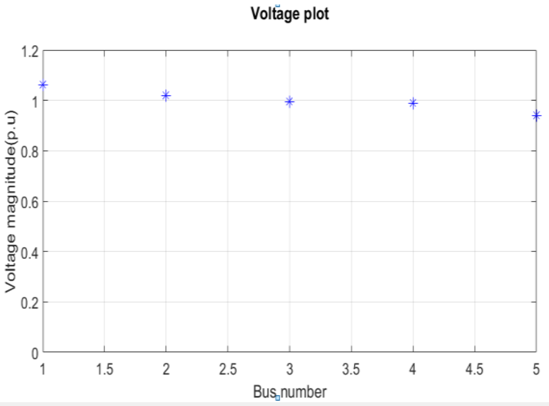


Figure 7: Voltage magnitude plot for IEEE 05 bus with ABC optimization

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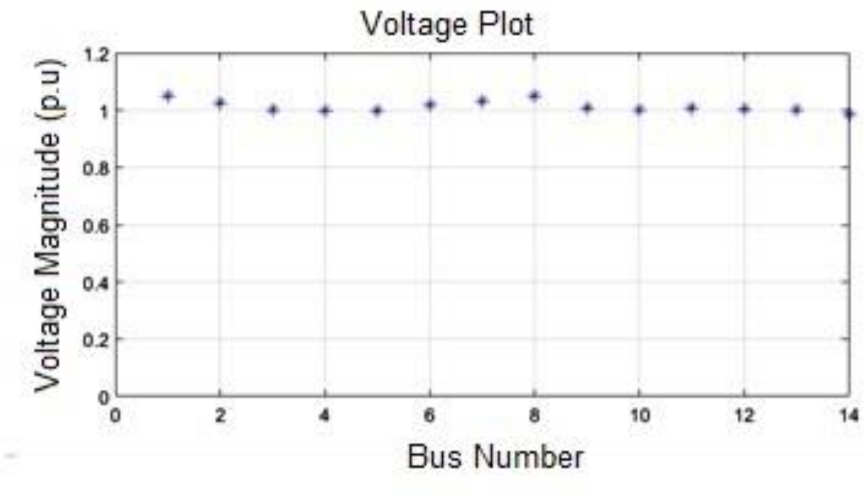

Figure 8: Voltage magnitude with respect to bus no for IEEE 14 bus with GA optimization

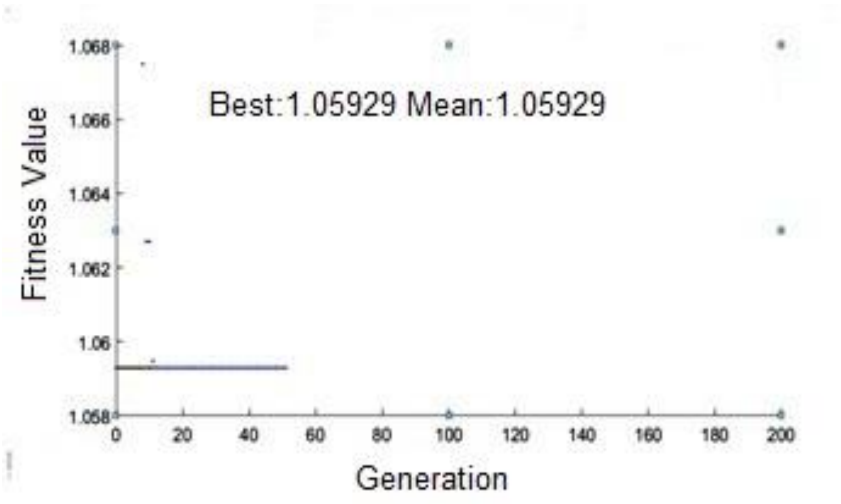

Figure 9: fitness plot with Generation for IEEE 14 bus with GA optimization

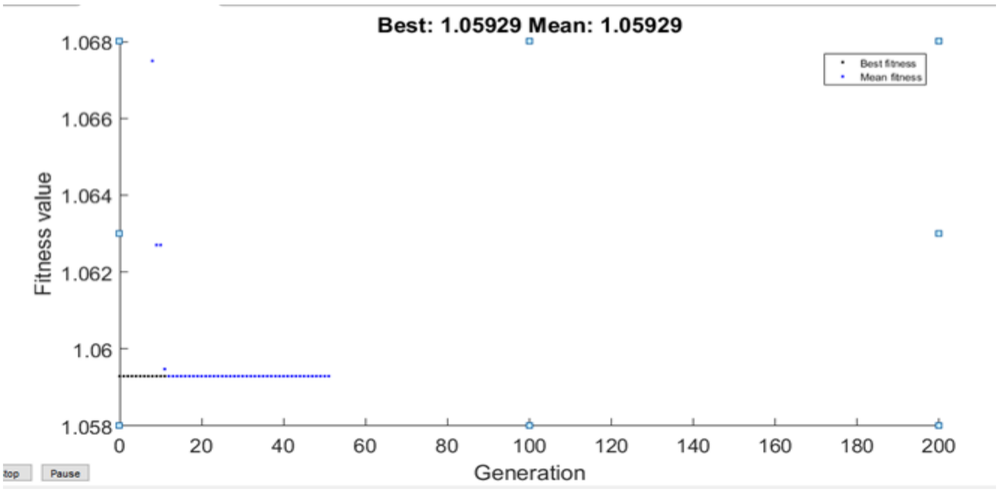

Figure 10 .fitness plot with generation for IEEE 05 bus with GA optimization

Table 1.result in analysis of GA and ABC method for IEEE 5 and IEEE 14 Bus system

IEEE 14	IEEE 05	ABC 14 BUS SYSTEM	ABC IEEE 5 BUS	GA IEEE 14 BUS	GA IEEE5 bus
MaxVm= 1.0800	MaxVm= 1.0600	MaxVm= 1.0500	MaxVm= 1.0600	MaxVm =1.0500	MaxVm =1.0600
MinVm =1.0064	MinVm = 0.9901	MinVm= 0.9955	MinVm= 0.9409	MinVm= 0.9838	MinVm =0.9823
ploss = 13.85	ploss = 3.0526	ploss= 11.8280	ploss = 6.5430	ploss= 11.8549	ploss = 3.156
qloss= 32.696	qloss =-21.767	qloss= 23.4160	qloss = -9.7320	qloss= 24.4858	qloss= -21.196
		ans = 1.1041		ans = 1.0593	
		The optimally placed FACT as FACTS locations = 2	The optimally placed FACT as FACTS locations = 5	The optimally placed FACT as FACTS locations = 6	The optimally placed FACT as FACTS locations = 2
		FACT sizes (MVar) = -1 x = -1 2	and = Inf FACT sizes(MVar)= -6 x = -6 5	FACT sizes (MVar)= -8 x = -8 6	and = Inf FACT sizes (MVar)= -1 x = -1 2

CONCLUSION

We discussed the essential traits of FACTS controllers and how they might improve network stability for power systems. Flexible AC Transmission System (FACTS), a technology-based system, helps the utility sector adapt to changes in the electricity distribution sector. The operation of electricity systems is essentially made more flexible by the FACTS devices. This allows for even more freedom in the independent adjustment of specific system characteristics, which are frequently used to differentiate the controlled parameters of FACTS devices due to the electronic realization of such devices. There are devices available to control line series reactance, the angle of a phase-shifting transformer, or a combination of these. After debate and correction of the line from the result, it was determined that the IEEE 14 bus system's ABC is the best method to place the facts device to reduce the loss in the system and improve the voltage profile because the loss will be higher and power flow will be reduced in the absence of facts device and optimization technique. However, in the case of the IEEE 5 bus, the loss is concerned, the real power loss is very little in the ABC method as compared to the GA optimization method.

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